# PRELIMINARY REPORT ON OBSERVATIONS OF AIR CELLS IN SNOWFLAKES AND IN OTHER FORMS OF ICE

By CHARLES M. HECK

[North Carolina State College, University of North Carolina, Raleigh, N. C., September 1937]

Examining snowflakes that were in the process of melting immediately after they had fallen, early in the spring of 1936, the writer observed that when the melting line through a snowflake reached one end of a long, regular air cell in the flake and punctured its wall, water ran up into the air cell for approximately 40 percent of its length. The facilities for observation during that snowfall were not very good, but the striking fact was noted that the air in all cells showed practically this same 40 percent contraction.

This phenomenon is of considerable physical interest, and also suggests a possibility of practical application. If the principal cause of the contraction of the air in the cells is the higher barometric pressure at the earth's surface, then from the standard hypsometric formula the height at which the snow was formed may be inferred; it was hoped that further investigation would indicate what corrections would have to be introduced for temperature change, vapor pressure, and capillarity.

No more snows in 1936, and only one in 1937, presented opportunity for further observations In the 1937 snow, consistent values of 36 percent were found for the contraction of the air in the cells. In the meantime, observations were begun on air cells in other forms of ice.

Air cells in the following three forms of ice have been examined: (1) Ice formed in variously shaped concrete vessels, (2) thin ice layers formed over puddles, (3) ice columns rising from the ground on cold nights.

Six massive cement blocks were cast, with cavities in the form of a circle, an ellipse, a square, a rectangle, a triangle, and a six-pointed star; six others were also cast with dimensions one-third those of the first six. Each of the cakes of ice slowly frozen in these cavities during cold nights formed characteristic patterns of long air cells throughout the volume. These patterns were suggestive of stress lines developed during freezing, and varied somewhat with the rate of freezing. Photographs were made of the patterns, but a more accurate control of freezing conditions is needed before results are reproducible. The air in these cells showed no contraction on melting.

Air cells in thin ice layers are likewise not observed to contract on melting, but the shapes these air cells take are found to be very characteristic. Instead of being straight and regular, they tend to bend at one or more points at an angle of approximately 120°. The natural assumption is that the air has been expelled to the edge of the ice crystal during freezing, and the 120° angles are found at the points where the air cells along two edges of a crystal meet. Observations under high magnification on the freezing of water at an interface with a mineral oil, showed the formation of ice under these conditions to be the result of a number of more or less distinct steps, and the formation of air cells was visibly associated with only the last of these steps. H. T. Barnes [1] has photographed one of the intermediate steps in the formation of ice on a free water surface; the winter's observations under the above conditions showed what Barnes called "colloidal ice" particles to be elongated rather than circular as shown in Barnes' photograph. These phenomena are to be further studied and photographed; they are mentioned to show that it is unsafe to assume too much simplicity in the manner in which air cells may be formed in ice.

The columns of ice often forced up from the ground on cold nights are found to be filled with many long, parallel air cells. Those observed were not as regular as the air cells in snow, and varied much more in diameter among contiguous parallel cells. When a line of melting punctures one end of one of these air cells, an air bubble immediately starts to form as though the pressure of the air within were slightly greater than that of the external atmosphere. Since the capillary pressure in the bubble must be less than that in the air cell, and grow still less as the bubble grows greater, the bubble naturally tends to grow larger. This causes a break in the air column about the middle of the length of the remaining air cell. The air bubble then separates from the air cell, and water runs up into the air cell half or more of its length. Thus the phenomena observed in air cells of melting frost columns are entirely different from those found in air cells of melting snowflakes; the former seem to have an excess air pressure, while the latter have a deficiency of pressure relative to the surrounding air.

The Weather Bureau has cooperated with the writer by arranging for observations of air cells in snowflakes at three Weather Bureau stations where the aid of university physics departments may be obtained. A few preliminary results that have been reported have corroborated the peculiar contraction of the air in the cells of snowflakes, and have given values between the 36 percent and 40 percent originally found. Means for artificially producing snow have also been devised for this study.

Correspondence and cooperation with the author on the part of any who may wish to observe air cells in snow or ice are invited.

[1] H. T. Barnes, *Ice Engineering*, p. 8.

# FURTHER OBSERVATIONS ON THE NORTH AMERICAN HIGH-LEVEL ANTICYCLONE

By THOMAS R. REED

[Weather Bureau, San Francisco, Calif., July 1937]

Four years ago the author [1] drew attention to the existence in summer of a thermally-induced anticyclone in the upper air over the North American continent, and showed how it was related to certain aspects of weather in the western United States, such as the prevailing temperature inversion over the south Pacific Slope, the occurrence of "Sonora" and "Arizona" type rains in the Far Southwest, and the occasional prevalence of summer thundershowers in other parts of the normally dry Far West. The study was based on 3 years' collection of upper-wind statistics for the United States, and utilized resultant wind data for the 4,000 meter level as published in the MONTHLY WEATHER REVIEW for the years 1930, 1931, and 1932. The present study incorporates similar data which have

[1] Thomas R. Reed, "The North American High Level Anticyclone," MONTHLY WEATHER REVIEW, November 1933, vol. 61: 321-325.

accumulated since the first study was made, and embraces upper wind statistics for the period 1930–36, inclusive. The study, of course, deals only with the warmer months, June, July, August, and September, of each year, making a total of 28 months in all.[2]

The first fact to impress one in a survey of resultant wind charts for these months is the preponderance of times at which the anticyclone was centered east of the Rocky Mountains. In the 28 months considered it was found east of the Divide for 21 of them. In the other 7 months it was either centered west of the Divide or was too feebly developed to be classified.

Another feature, and one of some significance, was the evident association of the anticyclonic crest with an area of deficient rainfall underneath: 15 times out of the 21 in which its crest lay east of the Rockies a droughty condition prevailed over large parts of the Middle West or South; whereas in nearly every case in which the crest lay west of the Rockies, normal or above normal rainfall was recorded to the eastward of them. Considering the 14 midsummer months alone (July and August), there were 12 in which the crest lay east of the Rockies, and for 9 of them subnormal rainfall was recorded over wide areas.

In the endeavor to account for the exceptions, i. e., the nonoccurrence of drought when the position of the upper level anticyclone seemed to call for it, resultant wind data for the 2,000-meter level were examined; and significant results were obtained. This circulation, more or less associated with the North Atlantic anticyclone, is normally independent of the high-level anticyclone over the continent, and the two cells are geographically rather far apart. However, when drought conditions over large areas are accentuated, the two cells are found nearer together. In the 12 cases considered, only one exception to this rule was found and that was in August 1932, when the upper-level anticyclone was very poorly developed A fair inference would seem to be that when these two systems (one represented by winds at 4,000 meters and the other by winds at 2,000 meters) are widely separated, normal or above normal rains will be the rule, but that when they are close together the situation is favorable for drought.

There are ample physical explanations for the observed phenomena. For one, the subsidence going on in the high-level anticyclone is no doubt important. It is often in itself enough to account for the drought-producing lapse rate of temperature, characteristic of the rainless season in the Far West; Petterssen ascribes to it the existence of the so-called Ts air. He says:[3]

> This high-level anticyclone should be regarded as an independent cell between the Atlantic and Pacific cells of the general circulation. This new continental cell at high levels differs from the ordinary subtropical cells in the respect that it spreads above both the neighboring cells. This continental cell is undoubtedly responsible for the production of the warm and dry air aloft, which meteorologists usually call Ts.

The seeming inconsistency of describing the anticyclone as thermally induced and then making it responsible for warm and dry air aloft is satisfied by the explanation that, while warming below is requisite for its inception and maintenance, warming in the upper levels—once it has been formed—may be attributable to subsidence.

When the high-level anticyclone is well established over the Middle West or South, presumably this Ts air overspreads an abnormally large continental area, inducing a thermal structure resistant to convective processes.

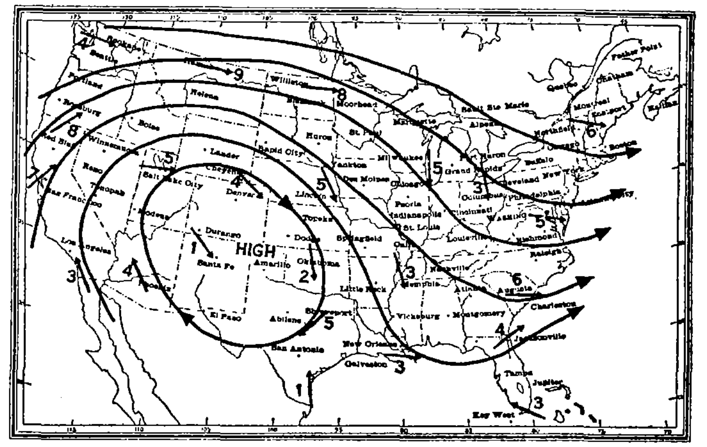


FIGURE 1.—August 1931. Resultant winds at 4,000 meters showing HIGH over Far Southwest.

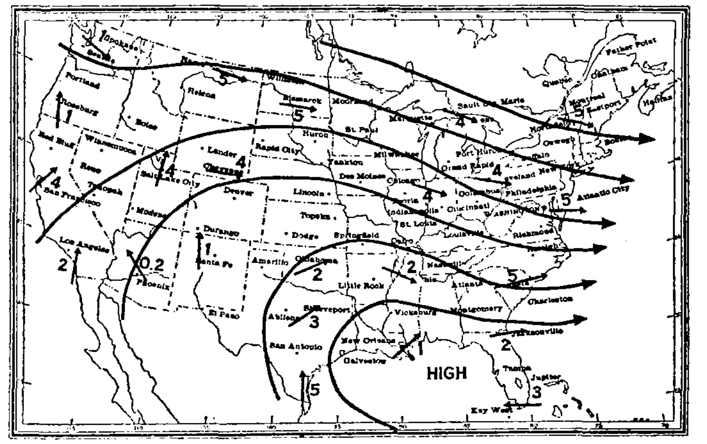


FIGURE 2.—August 1931. Resultant winds at 2,000 meters showing HIGH far to the Southeast. Note wide separation of this system with that shown in figure 1; rainfall was near or above normal east of Rockies with marked excess in Mississippi Basin.

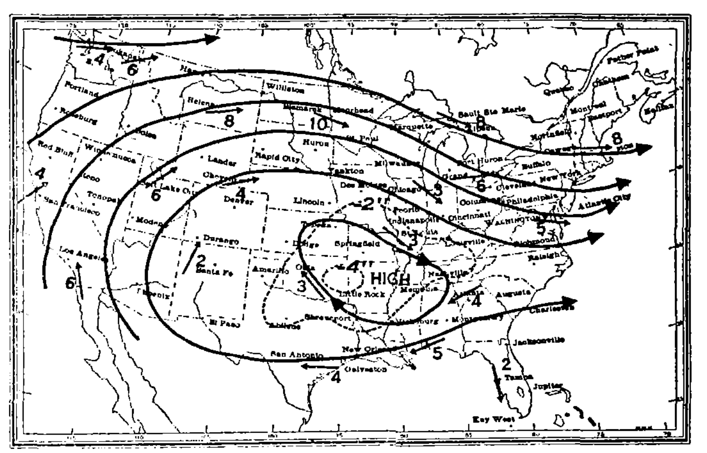


FIGURE 3.—August 1936. 4,000 meters. HIGH is over the Mississippi Valley.

It is not to be supposed, however, that the high-level circulation is all important. Air-mass movements below must be considered, and for this study the drift of air around the North Atlantic HIGH is fundamental. The relation of the North Atlantic HIGH to hot spells and droughts in the central and eastern United States has

[2] As in the previous study, the resultant wind data were plotted on charts, one chart for each month, after which stream lines were sketched in to represent roughly the mean air flow for the month over the entire region. In each case the flow was found to be anticyclonic with a fairly well implied crest or dome in the central area. Also, as before, data for the 4,000-meter level were employed as they yield the most consistent results for the country as a whole. Wind flow at lower levels is subject to more or less deformity due to the height of western mountain ranges, while data for the 5,000-meter level are less complete.

[3] Sverre Petterssen "On the Causes and Forecasting of California Fog." Journal of Aeronautical Sciences, 3: 306, July 1936.

long been recognized by meterologists, but only in recent years have mean values for the free-air circulation around its western extremity become available, and for the

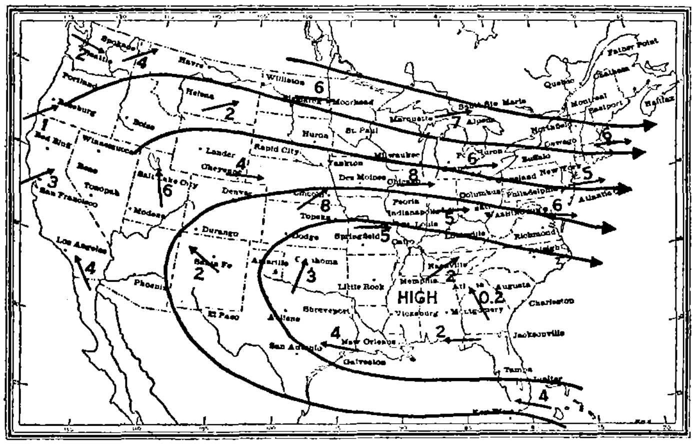


FIGURE 4.—August 1936. 2,000 meters. Note the merging of this system with that shown in figure 3; one HIGH being found almost above the other. This was a notably droughty month east of the Rockies.

FIGURE 5.—May 1935. Resultant winds at 2,000 meters. Circulation preceding a summer of nearly normal precipitation east of Rockies.

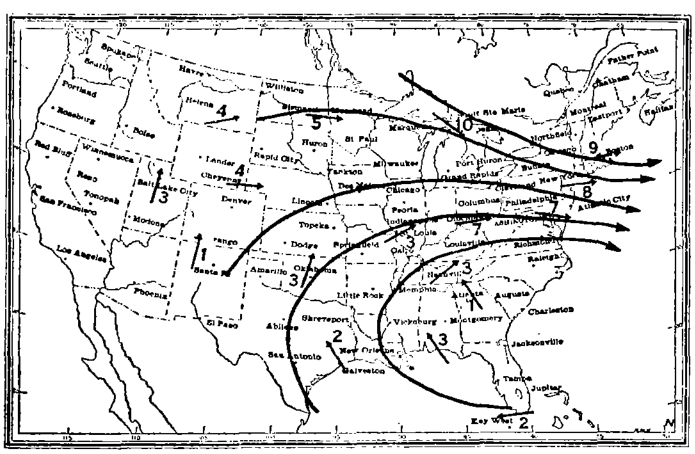

FIGURE 6.—May 1936. Resultant winds at 2,000 meters. Circulation preceding summer of extreme drought. Note encroachment of anticyclonic system over the Southeastern States.

present purpose they yield results which surface data do not. Air trajectories implied by resultant wind data at the 2,000-meter level reveal the withdrawal or encroachment, the strengthening or enfeeblement, of the North Atlantic HIGH more clearly than do surface data, and they also facilitate analysis of the relationship of the North Atlantic HIGH to drought conditions in connection with the high-level anticyclone.

It should not seem surprising to find that when these two systems overlap each other the least, droughts are least likely, for at such times the development of frontal disturbances between them is favored. The reverse, however, would naturally be the case when the two systems are located one above the other, for then, in addition to the "deck" of Ts air aloft, there is a uniformity of circulation at all levels tending to stagnation and unfavorable to frontal phenomena.

Contrasting situations indicative of the foregoing are represented on the charts for August 1931 (figs. 1 and 2) and August 1936 (figs. 3 and 4). Note that in August 1931, the high-level anticyclone is centered over the southern Rockies and scarcely overlaps the Atlantic anticyclone at all. This was a month of normal or supernormal rainfall east of the Continental Divide. In contrast to this is the coincidence of the two systems shown on the charts for August 1936. Here the anticyclonic circulation at the 2,000-meter level has invaded the continent as far west as the Rockies, while the high-level anticyclone is centered over Arkansas. This was a month of marked rainfall deficiency in the Middle West, with a defect of 2 inches or more throughout Missouri, Arkansas, Oklahoma, and parts of the adjoining States. Many examples like the foregoing can easily be found; those who wish to pursue the investigation are invited to examine in particular free air winds and attendant rainfall situations for the months of June and July 1936 (unusual droughts), and for June 1935 and July 1931, for opposite regimes.

Two exceptions to the foregoing rule are to be noted, both occurred in the month of September, once in 1933 and again in 1936. In both these months there was a marked overlapping of the two systems, but in each case the abnormality lay in the high-level system which was so far southeast of its usual position that its crest was over the East Gulf States. In both these instances there was an area of subnormal rainfall underneath the crest, but the periphery was marked by abundant rains, above normal precipitation being recorded over a wide belt extending from Texas to the Great Lakes, a fact not at all inconsistent, since the mean circulation implied a vast importation of Tg air over the belt mentioned.

Upper-wind data for the month of May seem to have some association with the type of weather during the ensuing summer. In this connection, the circulation at the 2,000-meter level is of especial interest. When the circulation at this level in May implies a normal flow (fig. 5) of air around the Atlantic high-pressure belt there is apparently less likelihood of drought in the following months than when it shows marked aberrations (fig. 6). In the inclusive period 1930–36 there was only one case in which this indication failed; that was in 1930, which was a droughty season although the May circulation did not appear to be seriously deranged. On the other hand, the droughts of 1934 and 1936, and the more normal seasons of 1931, 1932, 1933, and 1935 were fairly well presaged.